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COLLABORATIVE AND SUSTAINABLE SUPPLY CHAIN PRACTICES: A CASE STUDY

Abstract

Purpose: The purpose of this paper is to explore sustainability and collaboration in supply chain management designs and to develop a sustainable supply chain design model.

Design/Methodology/Approach: First, a literature review of the principal theories and supply chain management approaches is discussed. Second, the development of a sustainable supply chain design model is described and explained. Third, the results and the operationalization of the model, which incorporates sustainable procurement elements based on the results of interviews from a case study, are outlined.

Findings: A framework is proposed to provide managers, practitioners and academics with a practical solution to make sustainable supply chain decisions in a more structured and consistent manner.

Originality/value: The paper presents a currently discussed problem about the design of differentiated Supply Chains in order to avoid or offset the effects of allocation issues in the electronic marketplace. Although past literature reviews provide valuable results, they were based upon the assessment of Supply Chain decisions failing to consider the Corporate Social Responsibility sustainable and the interaction criteria. The findings from this article highlight the importance of addressing Supply Chain decisions in a structured manner, prioritizing the development of dynamic capabilities in order to improve the firm’s ability to reconfigure internal and external competences to address rapidly changing environments and reinforce a collaborative supply chain management system with third parties.

Keywords: case study, decision framework, sustainability, supply chain management, corporate social responsibility

Article Classification: Case Study

1. INTRODUCTION

More and more firms have a love-hate relationship between increasing or reducing inventory. On the one hand, inventory generates a temporary loss for the firm, while on the other it is necessary to build up safety stocks so that firms can improve delivery times, get product to market faster and exceed their customers' expectations. Inventory becomes increasingly expensive over time, which means the longer a firm holds its inventory, the more costly it becomes. What makes the situation even worse is the fact that many firms fail to take into account dynamic capabilities once they choose a supply chain design to build up their inventory. According to Teece, Pisano and Shuen (1997), "dynamic capabilities are the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments". Product innovation and organizational structure reconfiguration are examples of dynamic capabilities allowing firms to reconfigure their business units and recombine resources to adapt to environmental changes and provide a better performance (Ambrosini and Bowman, 2009). Dynamic capabilities are extremely important to efficiently react to market changes, for instance, when prices of components are increasing or the components are not available on the market or their lead times are extended.

The electronic component market is again facing shortages and causing original equipment manufacturers (OEMs) and electronics manufacturing services (EMSs) providers a real headache. Unfortunately, the current marketplace situation, with shortages of electronic and other components due to allocation, is certainly one of those times, and the conditions are still not improving and are set to continue in this way into 2019 (Sharp, 2018) (Baldock, 2018) (Future Electronics, 2018). Even if firms sign a consignment stock agreement with their suppliers and confirm their customer orders, delivery dates will be extended and final products will be more expensive. Probably this is not the time to ignore either market indicators or suppliers' resource positions. A risk is also taken when switching to a supplier that firms do not have experience with. Moreover, this way of purchasing requires more administrative costs and renegotiating efforts, and it can also delay the fulfillment of firms' new stock.

Taking as a starting point the electronic component market, the aim of this paper is to explore and update the supply chain literature by identifying past trends and developing a supply chain design model containing economic, environmental and social dimensions. As an OEM it is easy to lose touch with what is going on in the component marketplace – particularly when firms have taken the strategic decision to outsource their manufacturing to their external provider. In contrast to the majority of recent works, focused on minimizing cost or maximizing profit, this study addresses not only economic but also sustainability-related criteria in designing an effective and efficient supply chain strategy by proposing a supply chain design model.

The rest of the paper is organized as follows: Section 2 provides the literature review on supply chain management. In Section 3, the nine-stage supply chain design (SCD) model proposed is presented and described. In Section 4, the proposed model is explained and validated via a case study. Then, trends from experimental evaluations and analyses are presented in order to assess the effectiveness and efficiency of the proposed model in Section 5. Finally, the main conclusions and the topics related to this study which might be researched in the future as well as the limitations are presented in Section 6.

2. LITERATURE REVIEW ON SUPPLY CHAIN MANAGEMENT

Even though the dilemma faced by managers when it comes to choosing between agile or lean supply chain strategies has been studied by many researchers in the past, hybrid and multiple strategies involving sustainability aspects have not been considered. Whereas hybrid strategies refer to the combination of agile and lean strategies, multiple strategies result from the simultaneous use of supply chain management designs. Lean SCD is concerned with eliminating all the non-value-adding processes and thereby minimizing costs and cycle times (Hines and Rich, 1997), improving the quality and availability of the product (Vrijhoef and Koskela, 2000) through upstream and downstream flows of products, services and information that collaboratively work (Vitasek, Manrodt and Abbott, 2005). Whereas Tasdemir and Gazo (2018) stated that there is a need to develop a versatile tool that has the capability to assess and benchmark efficiency and sustainability of organizations and their supply chains, Martínez León and Calvo-Amodio (2017) posed the need for a consensus on definitions of lean and sustainability for achieving a successful integration.

Agile SCD, conversely, is suggested where demand is volatile and speed is the priority and concerned with the ability to quickly react to volatile demand and market characteristics in a priority manner (Mason-Jones, Naylo and Towill, 2000; Agarwal, Shankar and Tiwari, 2006) (source-to-order and market responsive). Hybrid strategies (leagile SCD strategies) are a combination of both methodologies and have been discussed by authors like Beck (2013), Christopher and Towill (2002), Haq and Boddu (2017), Olhager (2003, 2010) and Sun et al. (2008). Haq and Boddu (2017) posed that the leagile supply chain management paradigm which includes both lean and agile principles has attained greater importance in scenarios governed by unstable market trends, increased product variety and demand fluctuations.

Whereas the forecast-driven strategy preferred the make-to-stock (MtS), deliver-to-order (DtO) and assemble-to-order (AtO) strategies, the customer order-driven strategy is more suitable for the make-to-order (MtO), source-to-order (StO) and engineer-to-order (EtO) supply chain situations. Dallasega, Rauch and Frosolini (2018) presented "a lean approach for in engineer-to-order construction projects" splitting the job order in small lots allowing an optimal capacity saturation and reduction of non-productive and waste time.

According to Olhager (2010) the customer order decoupling point (CODP) divides the material flow that is forecast-driven (upstream of the CODP) from the flow that is customer order-driven (downstream of the CODP). Thus, the positioning inventory in the supply chain is planned gradually according to the CODP level with finished, semi-finished goods, and the stockage of assembly groups, components and raw material from tier 1-n. A lean supply chain should be applied for an upstream of the CODP, while an agile supply chain would be more suitable for downstream operations (Olhager, 2010). Leagile supply chains would be more suitable for middle point operations of the CODP like assemble-to-order (AtO) SCD (Beck, 2013).

The appropriate supply chain design should be selected in a structured, systematic and consistent manner. While Kumar BR, Agarwal and Sharma (2016) considered the environmental aspects in the design of supply chain strategies based on lean supply chains, Fathollahi-Fard, Hajiaghaei-Keshteli and Mirjalili (2018) developed a multi-objective stochastic closed-loop supply chain network design with social considerations. According to them, most current studies consider the economic aspects and just a few works present social considerations to design a supply chain network (Nieminen and Lemmetyinen, 2015; Pittz Thomas and Hertz, 2018).

3. SUSTAINABLE SUPPLY CHAIN DESIGN DECISION MODEL

The question was how to implement supply chain management principles in daily business reality. According to Shan and Wang (2018) there is a need to integrate environmental considerations into supply chain management. Thus, we propose in this section a model with an integrated framework to implement sustainable supply chain practices to solve this problem in a structured manner.

The paper focuses on the procurement phase between firms and their suppliers and the design of the most suitable SCD strategy to meet the respective customer needs. The phases of firms' internal processes, distribution and customer delivery as part of the SCD strategy are not included in this study, as they are addressed in another paper. The proposed *supply chain design* *decision model* is based on the ANP[1] (analytic network process) methodology which was developed by Saaty (1996) and the subsequent implementations by Gencer and Gürpinar (2007). The model was split into 9 steps: (1) analyzing of customer group; (2) analyzing of product group; (3) analyzing of external providers; (4) determining the goal and SCD criteria from the framework; (5) determining the alternative of external providers; (6) defining the weight of decision makers; (7) building different SCD scenarios; (8) making the paired comparison matrices (PCM); and (9) decision with the evaluation of preferred SCD using the TOPSIS methodology. Figure 1 illustrates the proposed model.

(1) The first process is ***analyzing customers*** who are interested in a specific product or service and classifying them into customer groups. For the assessment and definition of the different customer groups (CG), criteria like the interaction of the firm with the customers in terms of information sharing, collaboration, demanded influence on distribution and manufacturing are evaluated. Thus, future customers can be evaluated according to the above-mentioned criteria and classified into the previously defined CGs.

INSERT FIGURE 1

(2) Secondly, the following criteria are considered for ***analyzing the product group***: (1) duration of the product lifecycle; (2) windows for delivery; (3) demand volume; (4) demand variability; and (5) product variability. The evaluation is performed by rating the above-mentioned criteria and taking their interrelation into account.

(3) Thirdly, the ***analysis of external providers*** is performed by a multidisciplinary team mainly comprising the following: strategic purchasers, supplier quality managers, designers/developers and other players involved in the process, like industrial engineers. As part of the analysis of external providers, the corporate social responsibility (CSR) criterion is taken into account (Rhuks, Lawrence and Okonmah, 2009). The CSR considerations are subcategorized into the evaluation of environmental criteria (ISO 14001), occupational health and safety (ISO 45001), green energy (ISO 50001), conflict minerals (CMRT & REACH & RoHS) and the implementation of internal and second party codes of conduct (CoC). Interestingly, the interaction with Tier 1-2...-n suppliers is taken into account as a key relevant criterion for the consideration and evaluation of the whole supply chain.

(4) The fourth process is ***defining the goal and determining the most relevant criteria and subcriteria*** from the framework which must be highlighted and prioritized. A project with a milestone plan has to be set up. The definition of the required resources as well as the

[1] ANP structures a decision problem into a network and is used in multi-criteria decision analysis.

appointment of a project leader is more than mandatory to monitor and organize the tasks that different team members must deliver to meet the defined schedule. The framework is based on the definition proposed by Beck (2013) and further developed with the criteria regarding CSR sustainability and interaction with tier 1-n suppliers. The framework is illustrated in Figure 2.

INSERT FIGURE 2

(5) The next step is ***determining alternative of external providers*** in order to avoid possible shortages or interruptions in the supply chain structure. The interaction with tier 1-2-n for existing and alternative suppliers must be evaluated in terms of (1) information sharing; (2) supply chain risks; (2) market stability; (3) supplier resource position; (4) demanded influence on distribution; (5) demanded influence on manufacturing; and (6) collaboration. The will of the supplier to share information and confidential documentation with the firm, the trust in the supplier and the bidirectional collaboration with the focus on a win-to-win situation is even more relevant than just the economic criterion. The long-term relationship with suppliers can influence the firm to work with suppliers in the future because of positive results in the past.

(6) When ***choosing decision makers (DM)*** for the evaluation of different SCD scenarios, the ones selected for this study were those decision makers within the procurement process who were most willing to explain the decisions made at their workplace. Those decision makers are categorized into three levels: DM1, who are represented by purchase leaders; DM2, operative purchasers; and DM3, strategic purchasers. The weight of decision maker levels is set as follows according to the Boran et al. (2009)'s research: DM1 is 0.406; DM2 is 0.238; and DM3 is 0.356, so that the total of the weighting is 1.

(7) ***Different SCD scenarios were built*** by the above-mentioned decision makers in accordance with the CG and PG by means of our framework. In general, the material decoupling point refers to the physical allocation of the goods and indicates how deeply the customer order penetrates into the physical flow (Hoekstra and Romme 1992).

The factors considered in the SCD are the distribution channel, the SC strategy, the SC type, and the position of the decoupling point (Table 1). The information decoupling point is where information turns from the high value actual consumer demand data to the typical upstream distorted, magnified and delayed order data (Mason-Jones and Towill 1999). The consideration of a suitable SC type includes the positioning of the decoupling point (Olhager, 2003). Market information is mostly used to improve demand forecasts and enhance the operating capabilities, and it does not necessarily have to stop at the (material flow related) CODP (Olhager 2012).

A high interaction with the end customer, which includes frequently sharing sensitive information and forecasts, makes it possible to identify the value chain for a product (Kawharu, 2019). Whereas upstream of CODP is the form of "push" where the release of work is governed by forecasts and assumptions, downstream of CODP is the form of "pull" activities in the goods are planned and control based upon actual end customer orders. The collection of processes associated with ordering materials (raw materials, semi-finished products, finished products, goods, merchandise) and/or services for specific orders.

INSERT TABLE 1

A specific reference or customer order detail is exchanged with the supplying party, attached to or marked on the product, recorded in the warehousing or enterprise resource planning (ERP) system to track individual deliveries. Source-to-order is a MtO process which is preferred in cases like (1) purchasing to order; (2) just-in-time; (3) in a factory: ordering of configurable parts; and (4) in a retail store: special orders. Investing in research by creating a methodology for defining the "optimal" position of CODP for a closer and mutually beneficial cooperation with the suppliers and customers to improve customer satisfaction drives the focus on shifting CODP in upstream.

(8) The eighth process corresponds to the assessment (rating) of the ***paired comparison matrices*** (PCM). The decision makers involved are mainly the purchase leaders, and strategic and operative purchasers who are asked to respond to a series of pairwise comparisons where two criteria elements at a time are compared in terms of how they contribute to their corresponding upper level criterion. The consistency of each comparison was also checked in this step. The relative importance values are determined on a scale of 0 to 2, where a score of 0 represents less importance than the other criterion, a score of 1 indicates equal importance between the two elements, and a score of 2 indicates the maximum importance of one element (row component in the matrix) compared to the other one (column component in the matrix). The weighting of each criterion was then determined and adapted in the pairwise comparison matrix.

(9) Finally, a decision is taken based on ***the evaluation of the preferred SC design*** through a matrix built using the underlying logic of the technique for order preference by similarity to ideal solution (TOPSIS) and the criteria defined in the framework. The calculation of the matrix is based on the procedure defined in the research by Temuçin et al. (2013) and it is not explained in this study because is not the target of the present paper. TOPSIS is a well-known multiple criteria decision-making (MCDM) method which was originally developed by Hwang and Yoon (1981) to solve real-world decision problems. The TOPSIS method chooses alternatives that have shortest distance from positive ideal solution. The TOPSIS method has been analyzed using multi-criteria models for complex decisions and multiple attribute models for the most

preferable choice. Based on the matrix, each condition is evaluated on a scale of 1 to 5, where a score of 1 means that the condition does not meet the requirements, a score of 2 indicates that the requirements are only partly met, a score of 3 indicates that the requirements are almost completely fulfilled, a score of 4 means that the requirements are fully met and a score of 5 indicates that the condition reaches a level of excellence. The weightings of each criterion are then determined and adapted in the matrix. The best evaluated SCD scenario is the most recommended and the preferred one. However, multiple SCD scenarios can be applied depending on customer and product groups.

4. AN ILLUSTRATION OF THE MODEL USING A CASE STUDY

The case study will be useful to understand how supply chain design decisions are made in the practice. Lessons learned from interviews with decision makers (operative, strategic and lead purchasers) are collected in order to understand the interrelation between the firm, third parties and the factors and possible outcomes of SCD decision processes. In order to do this, an ongoing SCD decision considering the existing allocation issues in the electronic marketplace within an in-firm case study was analyzed and reviewed. Hence, a number of interviews were undertaken with decision makers at an electronic German firm. The interviews, their design, the analysis of the transcripts and how the findings were incorporated into the framework are described here. Semi-structured interviews with operative, strategic and lead purchasers were conducted. An interview questionnaire with a preliminary framework was designed based on Beck's (2013) research and served as an interview guide. Interview sessions took slots of over one hour and mainly covered the following topics:

- details of the interviewee
- areas related to the SCD
- triggers for SCD selection
- criteria to be considered during the SCD process
- functions involved in the SCD process
- relevant criteria for the SCD decision taken in the organization
- relevant financial elements during the SCD decision process
- strengths and weaknesses of ongoing and past decisions
- lessons learned and suggestions from ongoing and past decisions
- stages taken into account during the SCD decision process

The firm that was the object of the case study is a leading manufacturer of electrical products certified on NEC, CEC, ATEX, GOST, Inmetro and IECEx standards. The firm is a global player based in Germany with 1,788 employees and a €286.6 million turnover (key figures from the end of 2016). The main criteria for selection were that the firm had recently made SCD decisions on a specific product and that one of the authors has a professional relationship with the firm.

To undertake the in-firm case study, information was collected on how previous SCD decisions had been approached. The case study was carried out using evidence from multiple sources, such as a consignment stock agreement (CSA), a non-disclosure agreement (NDA), a confidential disclosure agreement (CDA), supplier self-disclosure forms, supplier selection assessments, quality assurance agreements (QAAs), supplier audit reports, delivery contracts, purchase orders, regular communication transcripts, final reports, demand planning and forecasting configuration at SAP and project plans, with a view to validity and reliability (Yin, 1994). The case study will also be useful to refine the model and illustrate how to use this framework. The external provider involved in this case study is an experienced printed circuit board assembly (PCBA) and electronics manufacturing services provider.

The firm is based in Germany and belongs to a Dutch corporation which is listed in the Reed Electronics Research Report of TOP European EMS-Providers in 2018. It has approximately 2,750 employees and a €439 million revenue (key figures from 2017). The firm is ISO 9001 (manufacturing), ISO/TS 16949 (automotive) and ISO 13485 (medicine) certified and also complies with RoHS, REACH and conflict minerals directives. Additionally, the firm has an internal code of conduct (CoC) which contains the main social criteria defined in ISO 26000. Yearly environmental and social targets are defined, documented and monitored. The firm obtained a green energy certificate according to ISO 50001 standards and its firm facility environmental control system is ISO 14001-certified.

4.1 Case study

In the following pages, we apply the model previously proposed and drawn in Figure 1 to our case study.

(1) ***Analyzing of customer groups***

The firm's customers were analyzed and categorized according to the decision makers into four different groups which are listed in Table 2. The four different groups were evaluated according to the information requested by customers: information sharing, distribution, manufacturing, sourcing and customer interaction and CSR criteria.

INSERT TABLE 2

(2) ***Analyzing of product groups***

Within the product or material group the products were classified according to the product groups defined in the firm based on the ABC-XYZ analysis tool which is used for the inventory management. This tool is implemented as part of the ERP system (SAP) of the firm and helps the firm focus on its most important stock-keeping units (SKUs). The product group classification is illustrated in Table 3. ABC analysis is a method of increasing the efficiency and effectiveness of the firm's sales and purchase system. The most common method of ABC analysis is used to optimize the range of goods (assortment) and its inventories in order to increase sales by identifying the most promising groups of products that bring the maximum profit for the firm (Chichulina and Skryl, 2018). This type of analysis is based on Pareto's rule: "20% of the products provide 80% of the firm's profits." In conducting product analysis, all goods are divided into three groups:

Group "A" - the most valuable goods; Group "B" - medium-value goods; and Group "C" - low-value goods.

INSERT TABLE 3

In order to take into account the randomness of sales and purchases, XYZ analysis is used. This method evaluates the stability of certain objects or processes (product sales, customer behavior, supplier behavior, employee efficiency, etc.). For instance, XYZ analysis makes it possible to group the firm's products according to the demand for a product over a period of time. Indeed, once the coefficients of variation of indicators of sales and purchases of goods for specified periods are determined, the goods are grouped accordingly into categories X, Y and Z. The coefficient of variation is very significant and representative and is calculated using the standard deviation and the mean ($CV = \sigma/\mu$). The window for delivery depends on the coefficient of variation.

Group X comprises goods that are characterized by stable demand (volume of purchases); therefore, there is a high probability of correct forecasting of purchases and sales. This is defined in the firm for products which are purchased monthly and for which, therefore, the value of the coefficient of variation is low. Group Y includes commodities with some fluctuations in sales volume. Forecasts on these products have average reliability. This is defined in the firm for products which are purchased quarterly and for which the value of the coefficient of variation is therefore medium. Group Z comprises products with irregular and unstable demand which are purchased yearly and for which sales cannot be forecast accurately. The value of the coefficient of variation is high. Whereas AX, BX and CX products are characterized by high trade turnover and stability and there is no need to create an excessive safety stock, the consumption stability for AY, BY and CY groups is low; therefore, it is recommended to increase their safety stock. AZ, BZ and CZ products are characterized by low predictability of consumption, which means it is difficult to plan an appropriate forecast (Chichulina and Skryl, 2018). The use of XYZ analysis can greatly reduce the time that a manager spends managing and controlling the products of this group. This case study focuses on a product which belongs to the worst combination, **AZ**. This product is a Field Device Coupler certified with IECEX and ATEX standards and can be used for fieldbus devices on the High Power Trunk protected by a short-circuit limiting function. An attempt to ensure the guaranteed presence of this product will lead to a significant increase in the average inventory of the enterprise. In the purchasing tab of the material master, purchasers can specify a manufacturer part profile. Thus, in the case study for the **AZ** product, the ongoing stock/requirements list for the part in a Manufacturer Part Number (MPN) - Material Requirements Planning (MRP) was set and specified in Figure 3. The replenishment lead time was set by 56 days and the minimum lot size by 24. Three days were set for performing incoming quality inspections.

INSERT FIGURE 3

No safety stock is available in the firm, but consignment stock is held at the supplier's warehouse named as "PS02", which is contractually agreed with the supplier. The minimum purchase order (PO) sized is defined according to the coefficient of variation, which is automatically calculated via SAP.

(3) The ***analysis of external providers*** was performed previously. Two suppliers were qualified to manufacture this product. However, it was internally decided to allocate the manufacturing of the product only to the supplier mentioned above, which has a manufacturing plant in Germany.

(4) ***Determining the goal and SCD criteria from the framework.*** This product is intended to enter into a market share and meet some customer-specific requirements. *The most critical viewpoint was the higher coefficient of variation, and the target is to shift the product from the AZ categorization into the AX, AY, BX, BY categories*. However, set-up costs for tooling and adapter tests must be invested.

(5) ***Determining alternative of external providers.*** Two suppliers were qualified and able to perform the manufacturing and testing processes of the product mentioned above. A second source supplier was already qualified and future purchase orders could be shifted to the alternative supplier.

(6) ***The weight of decision makers*** (operative and strategic purchasers and purchaser leaders) was previously defined in Section 3 and was applied for the evaluation of the different SCD scenarios.

(7) ***Three different SCD scenarios were built*** by the decision makers taking into account the above customer groups with varying levels of customer interaction each group requires. For instance, SC design scenarios are derived according to several possibilities to serve these customer groups. Interestingly, the downstream of the CODP in this case study strongly influences the output of all three scenarios.

a) ***SC design scenario 1*** considers a single SC design to serve the customer groups. Since the customer groups vary in terms of the information exchange they require, the firm must offer them various possibilities to submit their orders. Therefore, the firm would adopt a multichannel distribution strategy based on the supply from two external providers. Hence, it seems appropriate to adopt a leagile approach in a single SC design and to implement an EtO SC. Whereas the combination of multiple sourcing will increase the material costs and extremely increase the SC costs, the firm will have a better resource position to quickly supply its customers with low demand and high variability to fulfill the demand for a high customer influence on manufacturing. Moreover, the firm would be forced to manufacture the AZ product with low demand and high variability by means of MtS SC, which may involve extensive costs for storing these units.

b) ***SC design scenario 2*** adopts a single SC strategy based on a direct distribution focused on a single source strategy from a qualified supplier located in Germany. The firm signed a consignment stock agreement and agreed a minimum safety stock with its supplier to keep a defined amount of stock in the supplier's inventory. Bill Of Material (BOM) is cheaper for its supplier as the supplier purchases large amounts of electronic components. Due to the high coefficient of variation, the agile strategy would be the most suitable one based on the StO SCD type. Whereas the effectiveness of the SC cost using this SCD is higher, the firm's dependency on its supplier and the supplier's resource position can extend its window for delivery and its response to the customers. The firm can use the flextime system to increase or decrease its workforce resources if customer orders increase or decrease, efficiently saving its own resources.

c) ***SC design scenario 3*** incorporates the set-up of a single SCD based on a direct distribution channel. An agile strategy by means of an MtO SCD seems to be most suitable one to deal with the low demand and high variability of the product. This approach is cost-efficiency oriented and at the same time limited by the low level of customer interaction. Increasing customer interaction can help the firm have better forecast data and shift the product to the AX or AY area which is most beneficial for increasing the firm's revenue. The position of the product within the different SCD scenarios is summarized in Figure 4.

INSERT FIGURE 4

(8) ***Making the paired comparison matrices (PCM).*** For the weighting of the criteria pairwise comparisons were used for the different criteria from the framework which were applied to the three SCD scenarios. After the assessment, CSR and the cost of the SC design were defined as the most relevant criteria in the SCD decision. As presented in Figure 5, within the subcriteria of CSR, the code of conduct and social responsibility are the most important criteria. In the area of product and demand analysis, the criteria of demand volume and variability have the greatest weight. A possible revenue increase is the most important criterion within the positive effects of SCD. Customer interaction, supplier interaction and product and demand are of equal importance.

INSERT FIGURE 5

(9) ***TOPSIS application for the evaluation of supply chain design scenarios.*** Once the three design scenarios had been derived by means of the framework, a decision matrix based on the TOPSIS methodology was used to select the most appropriate SCD for the case study. Since the priorities of the pairwise comparison favor different solutions, an assessment of the different SCD was conducted, with a focus on the approach to the closest ideal solution. All subcriteria were integrated, and every main criterion was rated by the above-mentioned decision makers. After the evaluation of the defined SCD, scenario 3 seemed to be the ideal solution from the three cases, with a score of 87% out of a maximum of 100%, followed by scenario 2 with 77% and, finally, scenario 1 with a score of 59%. The SCD comparison is displayed in Figure 6.

INSERT FIGURE 6

5. DISCUSSION

Evaluation of changes and risks for AZ products is complexed and at the same time there is a need for firms to evaluate and prevent possible risks. However, the selection of the right supplier for this product type and the development of a collaborative supply chain management (CSCM) strategy can help firms solve, avoid or minimize shortage issues, thus favoring a win-to-win and long-term partnership situation. It was observed that there are some trends from experimental evaluations to take into account to improve firms' sustainable supply chain practices and supply SCD selection effectiveness:

1. *Taking into account second sources and alternative components and designs during the R&D phase* so that different electronic components are qualified and can be assembled if other parts are not available on the market. Listing alternative devices on their bill of materials (BOM) or separate approved vendors list (AVL) will make it easy for external providers to explore all options when they hit a supply issue. The engineering team should be in charge of reviewing the parts list to make sure every option can be explored in detail when allocation strikes. These components should be included in the firm's standard sheets.
2. *Increasing customer interaction*, trying to increase the regular communication with customers, sharing information, trends and information on possible future projects will shift the CODP from downstream to upstream.
3. *Focusing on activating the firm's suppliers and increasing the interaction with suppliers* from the beginning of new projects, with a preference for an upstream decoupling point based on forecasts and not only on actual customer orders, so that the window for delivery is decreased, favoring the increase in customers' expectations. It is also beneficial to share demand forecasts as much as possible with external providers so that they can procure the required component with their supply chain partners. Admittedly, a quick response to price and lead-time issues with external providers helps external suppliers quickly source the required material on the market without losing too much time in extra-costs agreements and extending lead times. Keramydas et al. (2017) proposed a methodology to minimize costs and CO2 emissions in supply chain network design; however, the interaction with tier 1-n suppliers and customers is key not only in reducing costs and CO2 emissions, but also in improving delivery times and collaboration, as well as in shifting to an upstream decoupling point.
4. *Reconfiguring organizational structures to improve internal and external dynamic capabilities*. Increasing the internal and external flow information is highly relevant for customers, external providers and the sales team to be regularly informed about the ongoing marketplace situation. While price increases often associated with allocation create conflicting involving suppliers, customers and end customers, explaining the reasoning behind them to customers can improve the customer-supplier relationship. Adequate actions should be adopted together with the marketing and sales departments to promote Z products into X and Y areas so that the SCD strategy can be changed and the profit can increase.
5. In addition to the trends proposed by Sharp (2018), the present study advocates the need to *promote and adopt internal and external policies to guarantee CSR criteria* all along the supply chain (tier 1-n) by preparing codes of conduct (CoC) for suppliers and

subcontractors. Our study is aligned with the Emamisaleh, Rahmani and Iranzadeh (2018)'s research of implementing a methodology for improving sustainable supplier management practices.

6. *Collaborative relationship with suppliers and customers* improved supply chain performance in several core areas. Trusting external providers and their buying team and supporting them in the raw material procurement process if firms have better material conditions and better networks. Customer meetings should be intensified to speed up critical orders (picking lists) and prioritize parts to complete full orders and finalize customers' orders quickly. A list of complete parts to complete the end customer's order should be specified and shared with the supplier (only for project-related orders). This is supported by the Haq and Boddu (2017)'s research results.
7. *Optimizing the supplier's resource position through the 7Ms* (machine, method, material, manpower, measurement, milieu and management). For instance, in the case study the supplier introduced a new SMD line to increase its production capacity.
8. *Monitoring suppliers and the market through defined KPIs* and performing supplier and subcontractor audits help anticipate trends. Information on replenishment lead times should be regularly updated into the ERP system (SAP) to have up-to-date figures and be able to determine realistic customer order confirmations. MRP is needed to procure the required quantities on time for fulfilling customer demands. It is also necessary to focus on both quality and on-time deliveries by establishing a system of rewards and economic sanctions in suppliers' contractual agreements depending on results. External providers should be asked to revalidate their quotations in terms of pricing, delivery and stock liabilities prior to sending them an official order to make sure they can still meet the agreed price and delivery expectations, even if a service level agreement (SLA) is in place. Electronic data interchange (EDI) and IT tools facilitate improved forecasts, management and reduced inventory and costs (Miao and Diu, 2013).

6. CONCLUSION

The research presented in this paper has significant theoretical and practical implications in the supply chain design management in general and the electronic marketplace in particular. The paper presented a currently discussed problem about the design of differentiated SCs in order to avoid or offset the effects of allocation issues in the electronic marketplace. Although past literature reviews like Beck (2013) provide valuable results, they were based upon the assessment of SCD decisions failing to consider the CSR sustainable and the tier 1-n interaction criteria. The findings from this article also highlight the importance of addressing SCD decisions in a structured manner, prioritizing the development of dynamic capabilities in order to improve the firm's ability to reconfigure internal and external competences to address rapidly changing environments and reinforce a collaborative supply chain management (CSCM) system with third parties. In contrast to the research works by Fathollahi-Farda, Hajiaghaei-Keshteli and Mirjalili (2018), who understood the concept of supply chain sustainability in social terms, this study extends this concept by additionally assessing environmental criteria in supply chain network design evaluations.

A multidisciplinary team should evaluate the possible risks and chances involved in dealing with SCD decisions through a suitable and adapted assessment tool. A nine-stage model for the SCD decision process which follows the trends observed in the literature reviewed has been proposed. This paper aims to contribute to the study of the SCD literature on supply chain management through the graphical representation of how SCD decisions are made. Interestingly, the paper presents relevant dimensions and factors to be studied and evaluates possible outcomes in approaching SCD decisions. While Kumar BR, Agarwal and Sharma (2016) considered the environmental aspects in the design of lean supply chain strategies, this article proposes a model where decision makers can evaluate which SC type (lean, leagile, agile) best fits the specific customer needs and product characteristics. Whereas Pinto Taborga, Lusa and Coves (2018) proposed a methodology based mainly on the corporate carbon strategy and the carbon emission roadmap, this paper argues that a sustainable supply chain strategy should consider customers, stakeholders and specific product requirements. Thus, sustainable strategies for PCB manufacturers would be different than for sheet molding compound (SMC) or elastomer manufacturers.

The perfect integration of the framework within the tool proposed provides managers, practitioners and academics with a practical solution to make decisions in a more structured and consistent manner. As observed in the case study, a better understanding of the lessons learned and improvement potentials should be considered for every future SCD decision. Hence, practitioners can learn from past failures by adapting future requirements and continuously updating the proposed framework and tool. The proposed model will involve a two-stage decision process: (1) the SCD decision and (2) the managerial actions required to implement the decision.

Notwithstanding the above findings and contributions, this study faced a number of limitations and so do its outcomes. Firstly, a potential limitation of this study stems from the fact that the in-depth analysis it presents is focused exclusively on one case study. As a consequence, the comparison with other case studies was not evaluated. Secondly, the development and integration of the presented model into a decision support methodology can be addressed. However, the findings from this study seem to provide a valuable understanding of the current situation in this research field. The present paper equally suggests several future research strands which may encourage more intensive studies in this important area. Researchers can develop the proposed framework integrating additional criteria for the evaluation and the prioritization of scenarios with the TOPSIS to enhance the approach's effectiveness. This paper presented a case study from the electronic industry. Case studies from other sectors can also be considered. Some specific research questions that can be explored in the future include: What are the challenges of Lean, Leagile, Agile and CSR implementation? Does the implementation of Lean and sustainability assist firms to be more efficient? Does the inclusion of the CSR criteria within the supply chain design decisions calls for a new theoretical foundation for quality improvement?

This article can prove useful for researchers and decision makers, since new trends are emerging in both areas that will probably lead to future research and implementation in firms. Hopefully, the present paper will give rise to a new approach to SCD decision practices. Nevertheless, a need exists to continue updating what is known about SCD decisions.

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Table 1. Type of SCD

Type of SCD	SCD strategy	Type of CODP	Comment
Make-to-Stock (MtS)	Lean	Upstream	Serving customers from finished goods inventory, keeping inventory in the distribution system, distributors, etc.
Deliver-to-Order (DtO)	Lean	Upstream	The deliver process that facilitates make-to-order.
Assemble-to-Order (AtO)	Leagile / Lean	Up- & medium stream	A number of preassembled modules are combined to meet customer's specifications; alternative components are carried in inventory.
Engineer-to-Order (EtO)	Leagile /Agile	Downstream	Working together with the customer to design and make the product.
Make-to-Order (MtO)	Agile	Downstream	Customer's product is made from the raw materials, parts and components, preferred for products with a wide range and low individual product volume per period.
Source-to-Order (StO)	Agile	Downstream	Order materials for explicit – identifiable – downstream demand.

Source: own source

Table 2. Customer group classification

Customer Group	Information sharing	Distribution	Manufacturing	Sourcing	CSR
CG 1 (large projects) Customer specific	High	Medium	Medium	Low	Medium
CG2 (medium-small projects) Customer specific	High	Medium	Medium	Low	Medium
CG3 (day-to-day operations) Customer specific	High	Medium	Medium	Medium	Medium
CG4 (day-to-day operations) Standard specification	Low	Low	Medium	Low	Medium

Source: case study

Table 3. Product group classification

Inventory Optimization ABC-XYZ Analysis			Sales frequency High X	Medium Y	Low Z
Material's value	High	A	AX	AY	AZ
	Medium	B	BX	BY	BZ
	Low	C	CX	CY	CZ

Source: case study

Figure 1. Flowchart for the proposed model for SCD decisions.

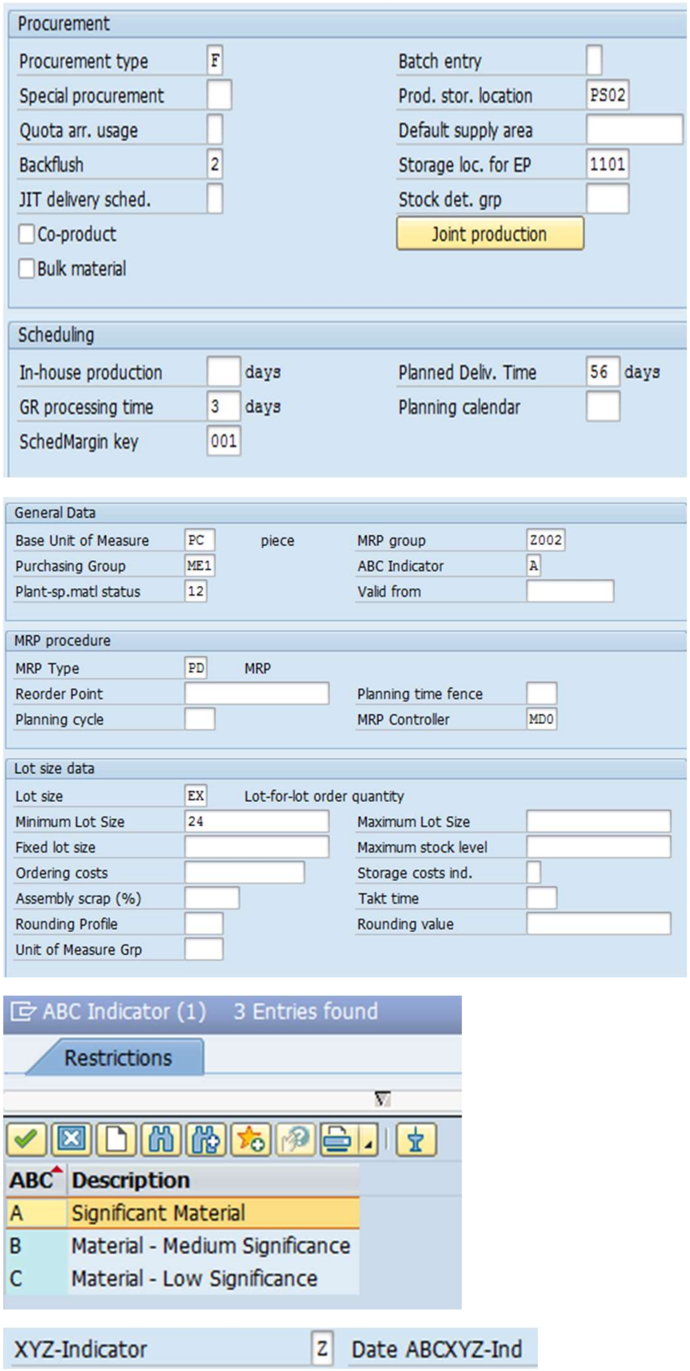
Source: own source.

Figure 2. The proposed SCD decision framework.

				Low / Short									High /Long
				1	2	3	4	5	6	7	8	9	10
Which is the most suitable SC design for the regarded market?	Effectiveness control	Customer interaction	Information sharing										
			Demanded influence on distribution										
			Demanded influence on manufacturing										
			Collaboration										
		Supplier interaction (Tier 1- 2..)	Information sharing										
			Supply chain risks										
			Market stability										
			Supplier resource position										
			Demanded influence on distribution										
			Demanded influence on manufacturing										
			Collaboration										
		Product and demand analysis	Duration of product lifecycle										
			Windows for delivery										
			Demand volume										
			Demand variability										
			Product variability										
		CSR	ISO 14001										
			ISO 45001										
			Code of Conduct										
			Conflict minerals (CMRT & REACH & RoHS)										
			ISO 50001										
	Efficiency constraint	Positive effects of SC design	Revenue increase										
			CSR increase										
			Higher customer proximity										
			Supply chain risks decrease										
			Dynamic capabilities increase										
			Resource position increase										
			Higher supplier proximity										
			Complexity decrease										
			Decrease in delivery lead time										
			Differentiated customer approach										
			Differentiated supplier approach										
		Costs of SC design	Manufacturing cost										
			Administration cost										
			Warehouse cost										
			Distribution cost										
			Hidden costs (auditing costs)										
			Installation cost										
			Capital cost										
	Out	Standardized SC design components	Distribution channel	Indirect			Multi-channel				Direct		
			SC Strategy	Lean			Leagile				Agile		
			Type of SC	MtS	DtO	AtO				EtO		MtO	StO
			Position of decoupling point	Upstream	--					Downstream			

Source: own source, developed from Beck's (2013) framework.

Figure 3. AZ Product- Material Requirements Planning (MRP)



Source: case study

Figure 4. SCD scenarios

SC design scenario 1							
Distribution channel	Indirect		**Multi-channel**			Direct	
SC Strategy	Lean		**Leagile**			Agile	
Type of SC	MtS	DtO	AtO	**EtO**		MtO	StO
Position of decoupling	Upstream		--				Downstream

SC design scenario 2							
Distribution channel	Indirect		Multi-channel			**Direct**	
SC Strategy	Lean		Leagile			**Agile**	
Type of SC	MtS	DtO	AtO	EtO		MtO	**StO**
Position of decoupling	Upstream		--				Downstream

SC design scenario 3							
Distribution channel	Indirect		Multi-channel			**Direct**	
SC Strategy	Lean		Leagile			**Agile**	
Type of SC	MtS	DtO	AtO	EtO		**MtO**	StO
Position of decoupling							

Source: case study

Figure 5. Pairwise comparison

Pairwise comparison — Determine the weights of criteria (more important than)

		Customer interaction	Supplier interaction (Tier 1-2..)	Product and demand analysis	CSR	Positive effects of SC design	Costs of SC design	Weight (%)-Factor
1	Customer interaction		2	1	1	1	0	6
2	Supplier interaction (Tier 1-2..)	1		2	1	1	1	6
3	Product and demand analysis	1	1		2	1	0	6
4	CSR	2	2	1		1	1	10
TOP1	ISO 14001	2	2	1		1	1	
TOP2	ISO 45001	2	2	1		1	1	
TOP3	Code of Conduct	2	2	2		1	1	
TOP4	Conflict minerals (CMRT & REACH & RoHS)	2	2	1		1	1	
TOP5	ISO 50001	2	1	1		1	1	
5	Positive effects of SC design	2	2	2	1		0	9
6	Costs of SC design	2	2	2	1	1		10

Source: case study

Figure 6. SCD comparison

SCD comparison

SCD scenarios → / Requirements ↓	EVALUATION SCD 1	SCD 2	SCD 3	Weight (%)-Factor	RESULTS SCD 1	SCD 2	SCD 3
Customer interaction	3	3	3	6	18	18	18
Supplier interaction (Tier 1-2..)	5	4	4	6	29	24	24
Product and demand analysis	5	4	4	6	29	24	24
CSR	4	5	5	10	44	50	50
Positive effects of SC design	4	3	4	9	34	31	36
Costs of SC design	1	3	4	10	10	34	40
DM1	1	3	4				
DM2	1	3	4				
DM3	1	4	4				
				Total	59%	77%	87%

Source: case study